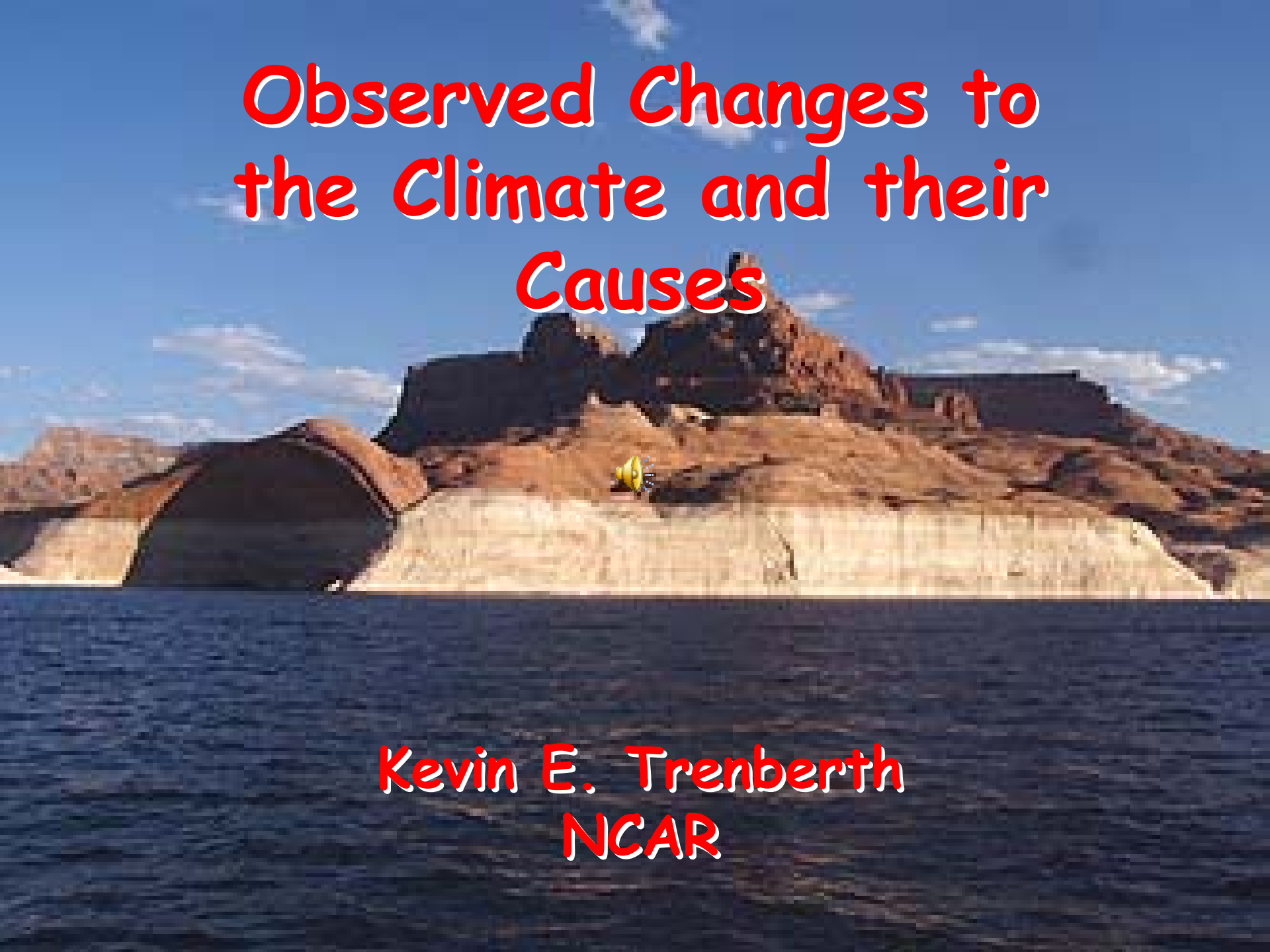
Observed Changes to the Climate and their Causes



Kevin E. Trenberth
NCAR

Climate

The atmosphere is a "global commons." Air over one place is typically half way round the world a week later, as shown by manned balloon flights.

The atmosphere is a dumping ground for all nations for pollution of all sorts. Some lasts a long time and is shared with all. **One consequence is global warming!**

Global Warming is happening

Since 1970, rise in:

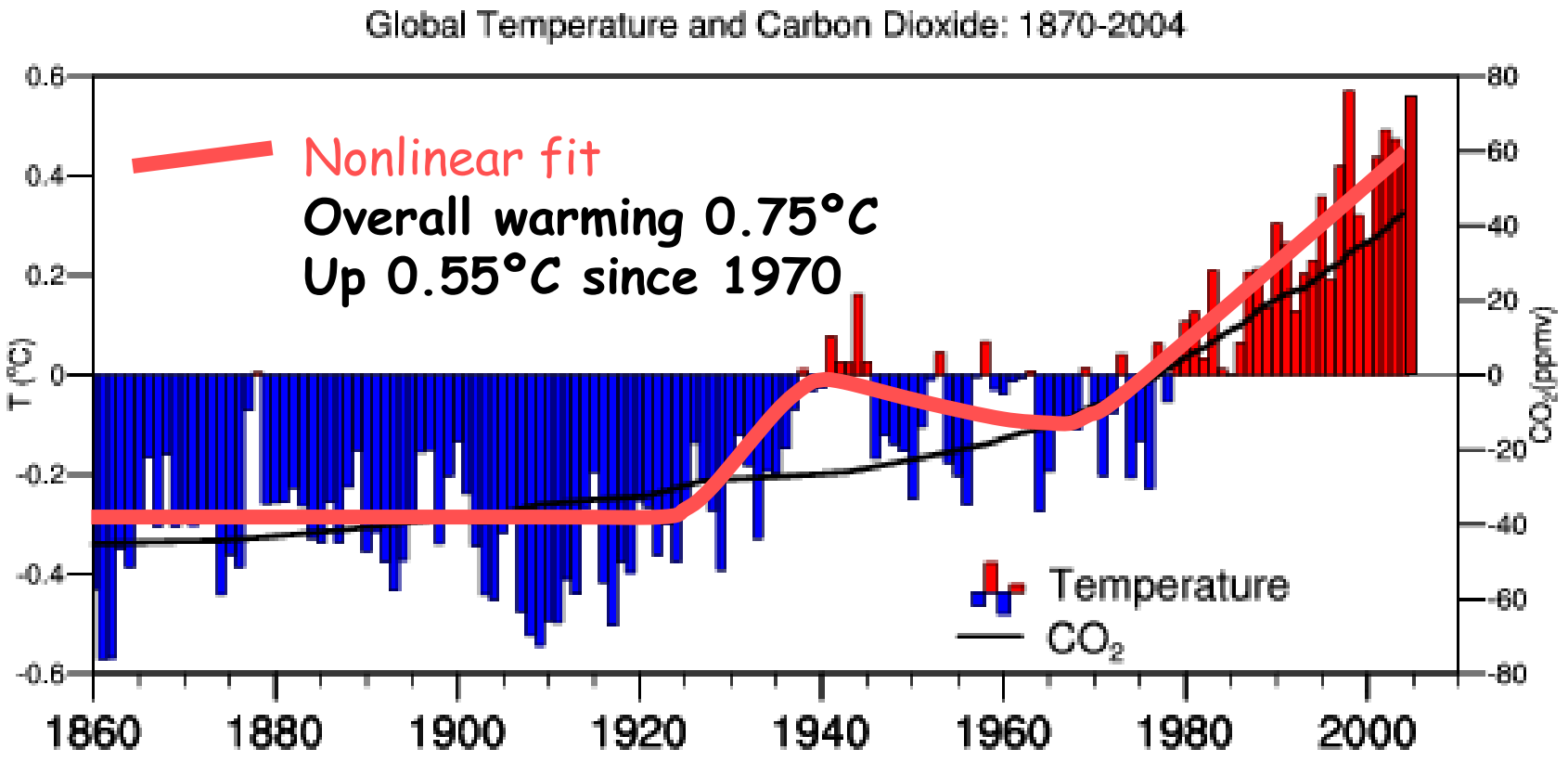
- Carbon Dioxide
- Global temperatures
- Global SSTs
- Global sea level
- Tropical SSTs
- Water vapour
- Rainfall intensity
- Precipitation extratropics
- Hurricane intensity
- Drought

Decrease in:

Snow extent

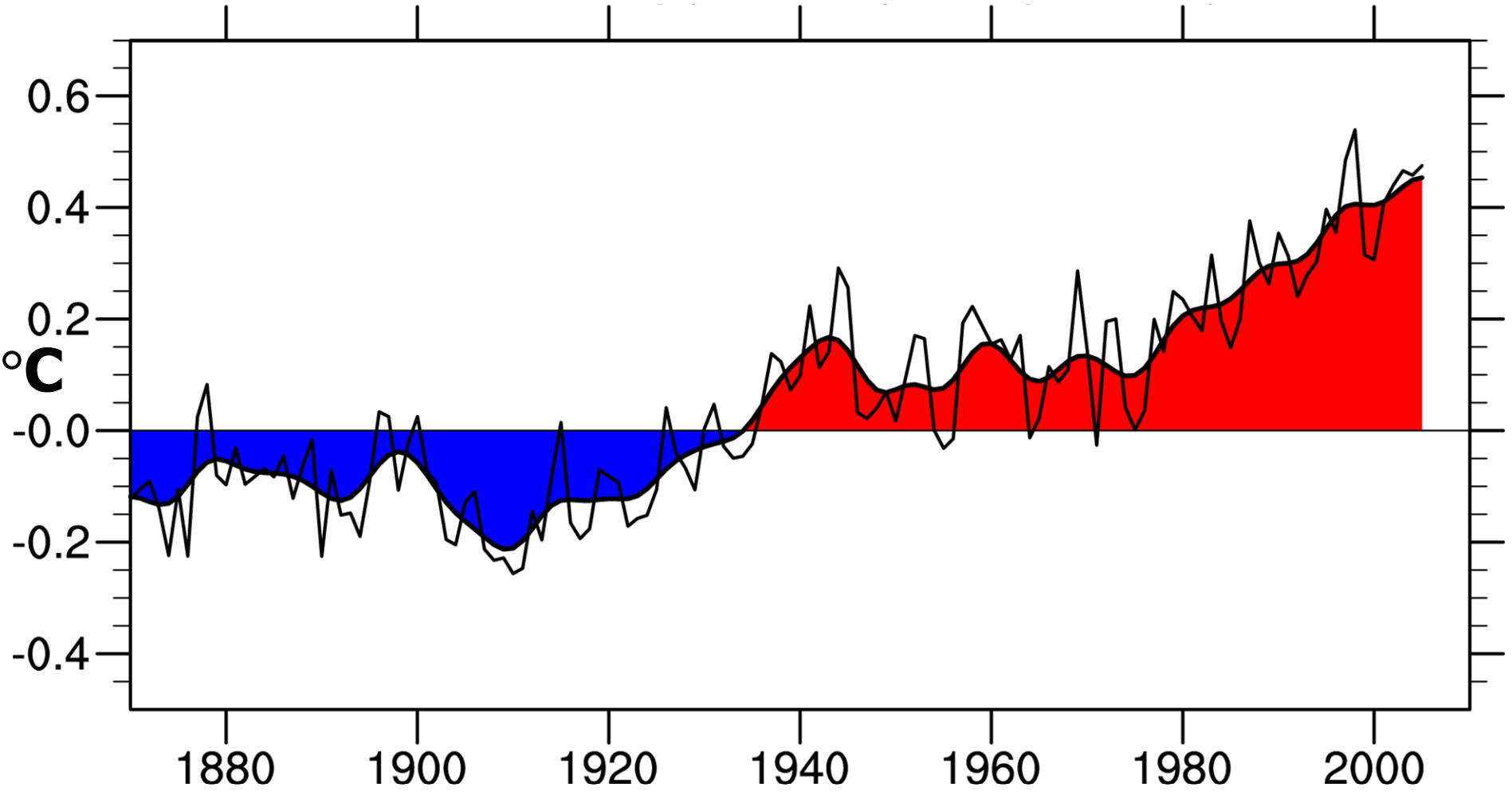
Arctic sea ice

Variations of the Earth's surface temperature

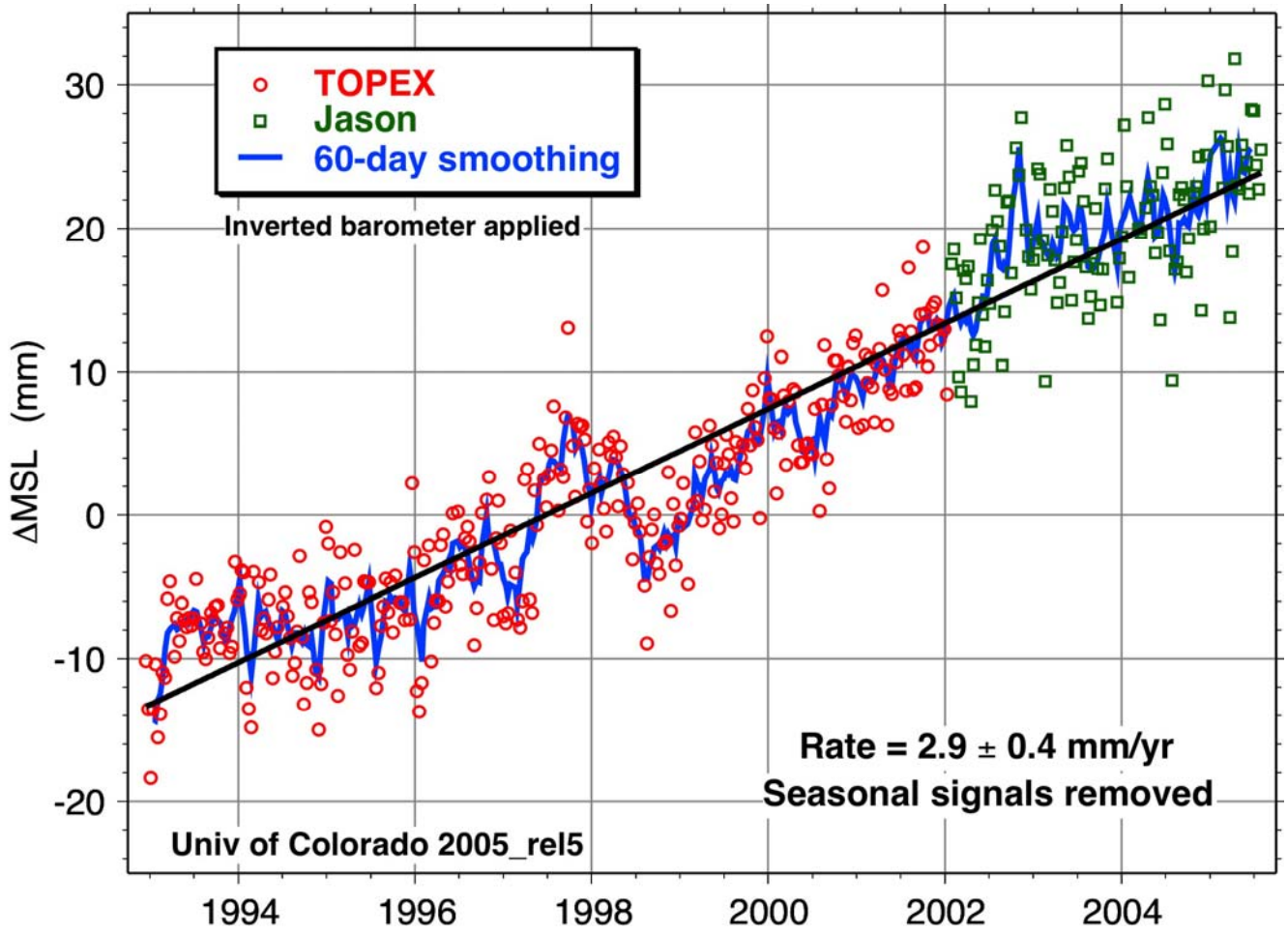


Annual mean departures from the 1961-90 average for global temperatures, mean 14.0°C, and carbon dioxide concentrations from ice cores and Mauna Loa (1958 on), mean 333.7 ppmv. Updated from Karl and Trenberth 2003.

Global Sea Surface Temperature: rel. to 1901-70



Sea level is rising:
from ocean expansion and melting glaciers



Since 1993 Global sea level has risen 37 mm (1.46 inches)

- 60% from expansion as ocean temperatures rise,
- 40% from melting glaciers

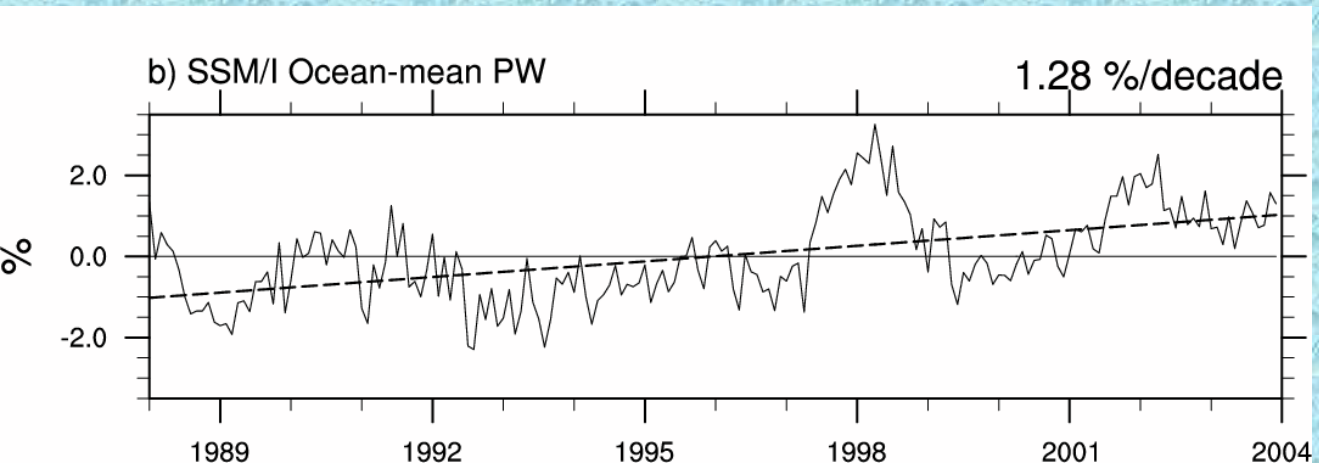
Steve Nerem

Total column water vapor is increasing:

A basic physical law tells us that the water holding capacity of the atmosphere goes up at about 7% per degree Celsius increase in temperature.

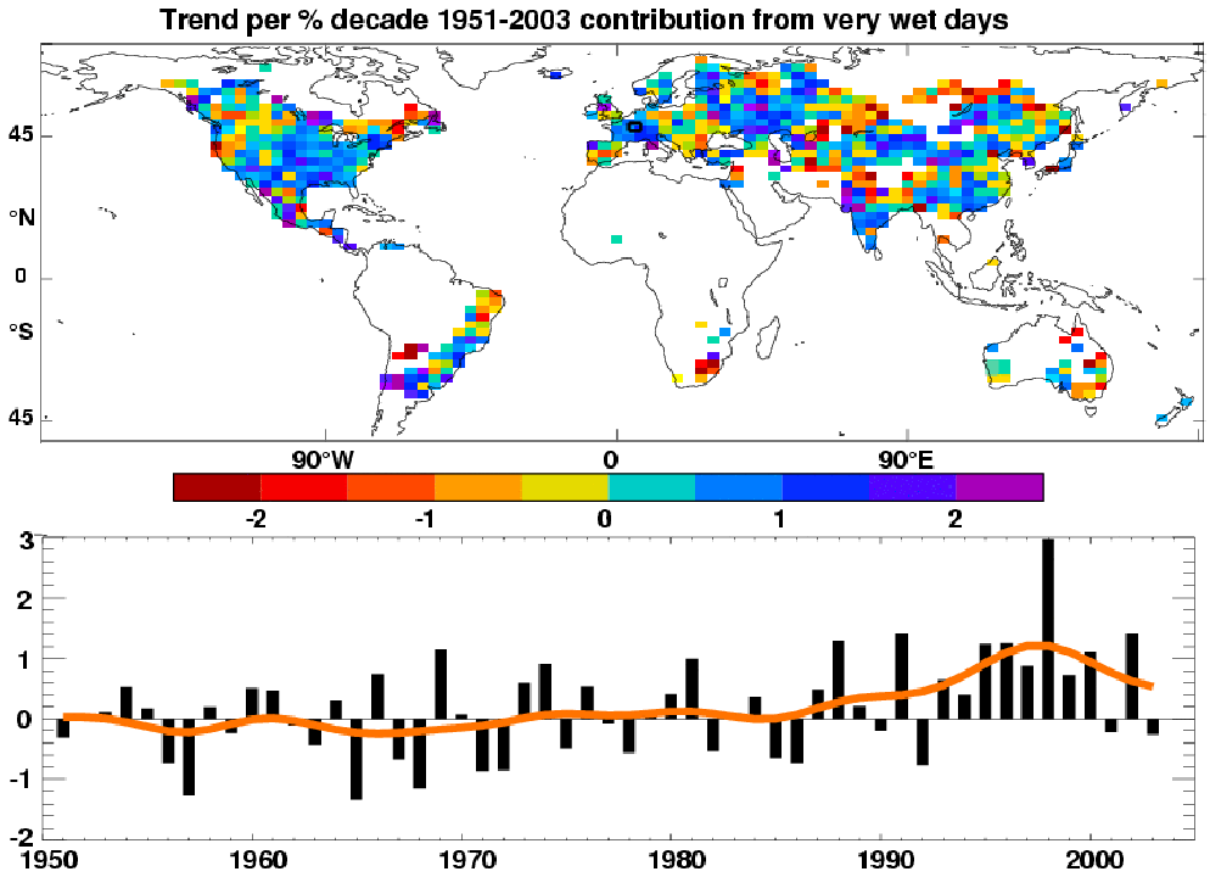
Observations show that this is happening at the surface and in lower atmosphere:

This means more moisture available for storms.



Trends:
Global ocean
1.3±0.3%
per decade
Trenberth et al 2005

Precipitation



Observed trends (%) per decade for 1951–2003 contribution to total annual from **very wet days** > 95th %ile.

When it rains, it rains harder now than it used to!

Alexander et al 2006

Flooding: North Island New Zealand

Worst flooding in 100 years began
13 February 2004.
$200M damage,
19 bridges, power, communications, etc.

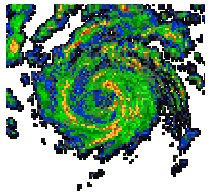
Note mud and sediment outflows into Tasman Sea

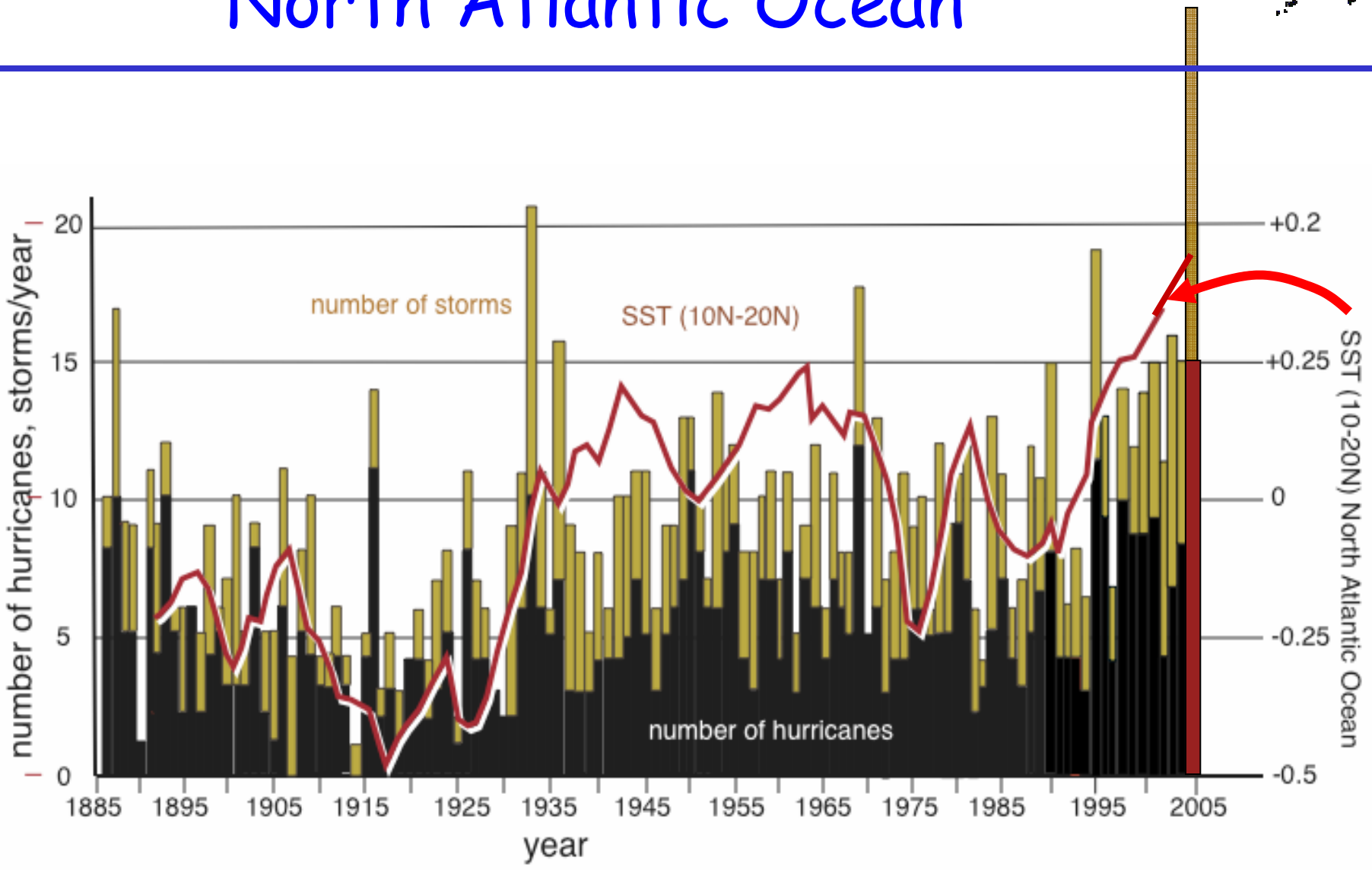
Courtesy: MODIS, NASA

February 25, 2004

January 17, 2004

Changes in **hurricanes** in the North Atlantic Ocean





Evidence for reality of climate change

Glaciers melting

1909

Toboggan Glacier Alaska

2000

1858 1974

Grindelwald Glacier

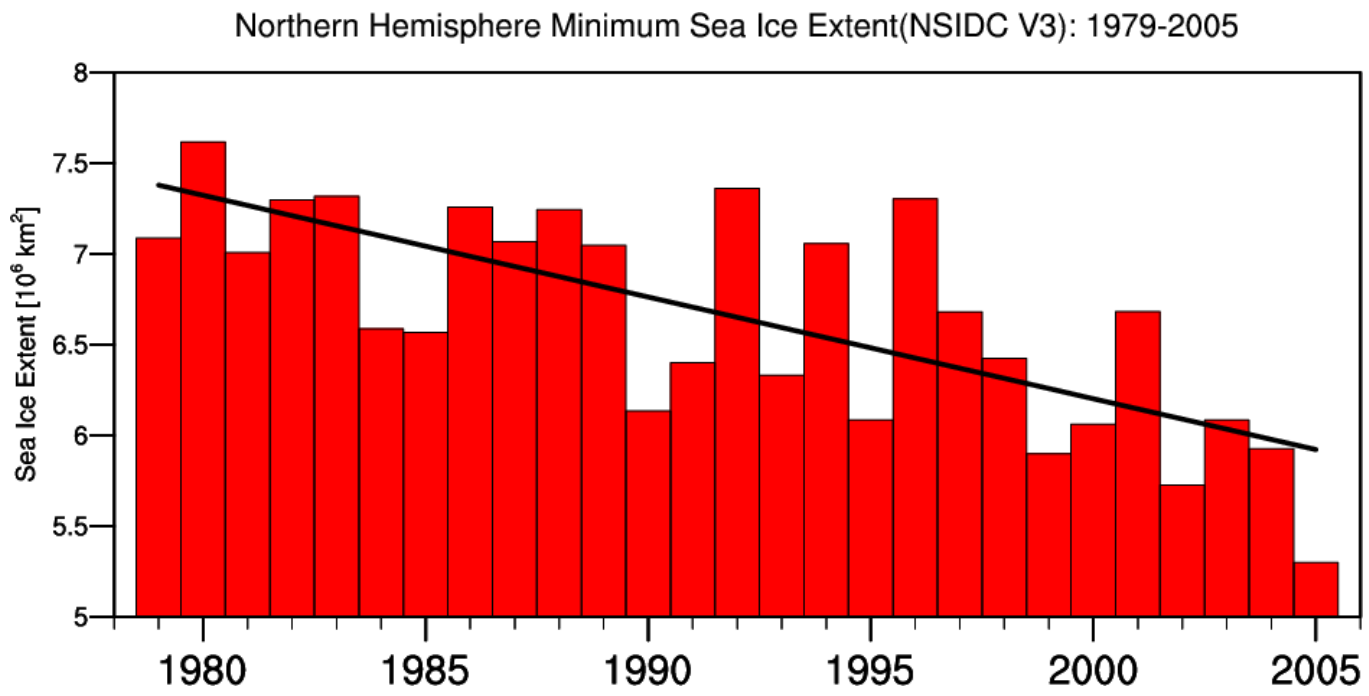
A. Circa 1900

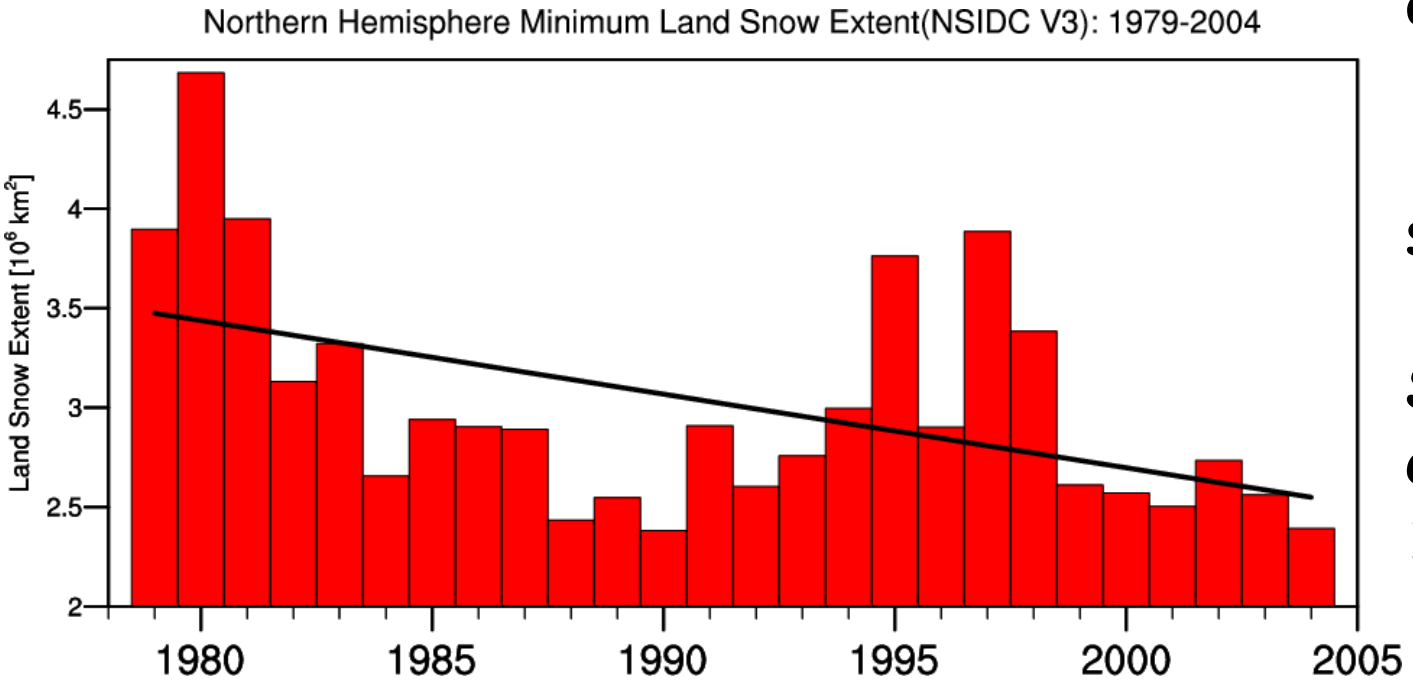
Photo Source: Munich Society for Environmental Research

B. Recent

1900 2003

Alpine glacier, Austria





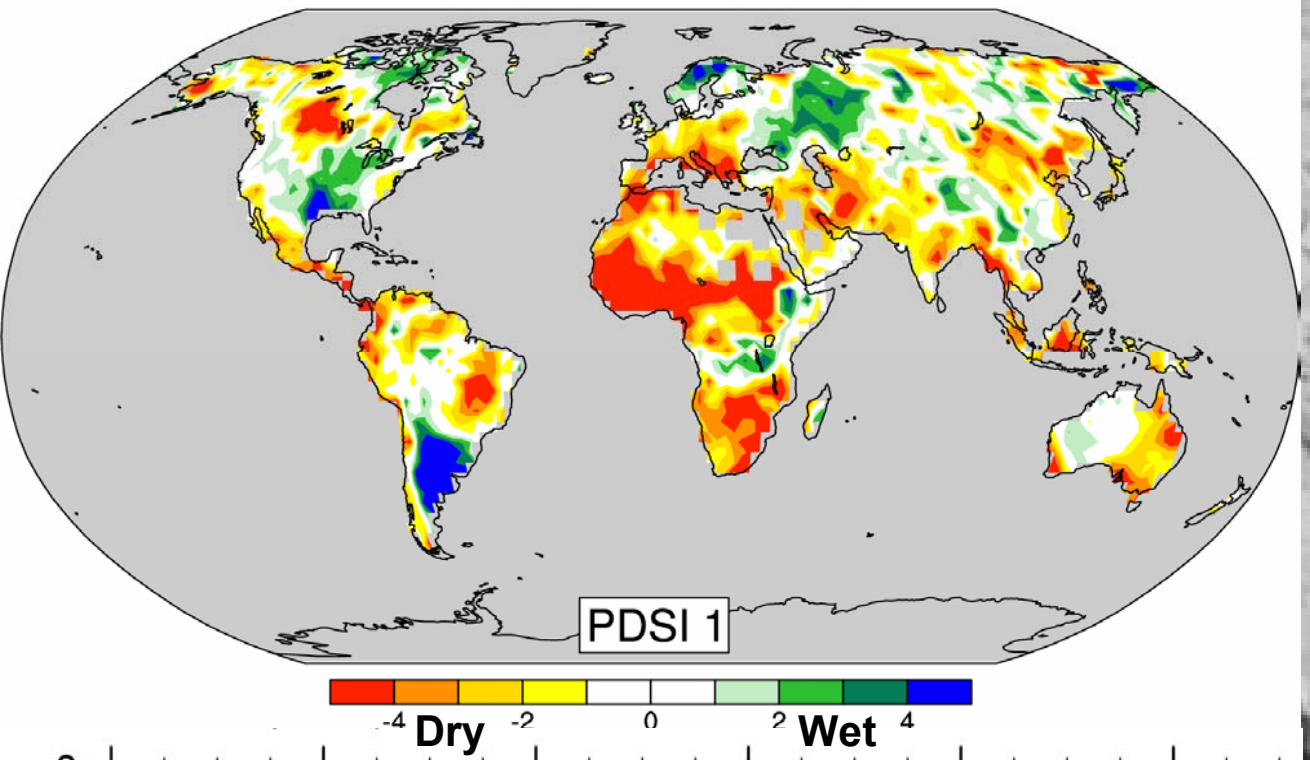
Declines in

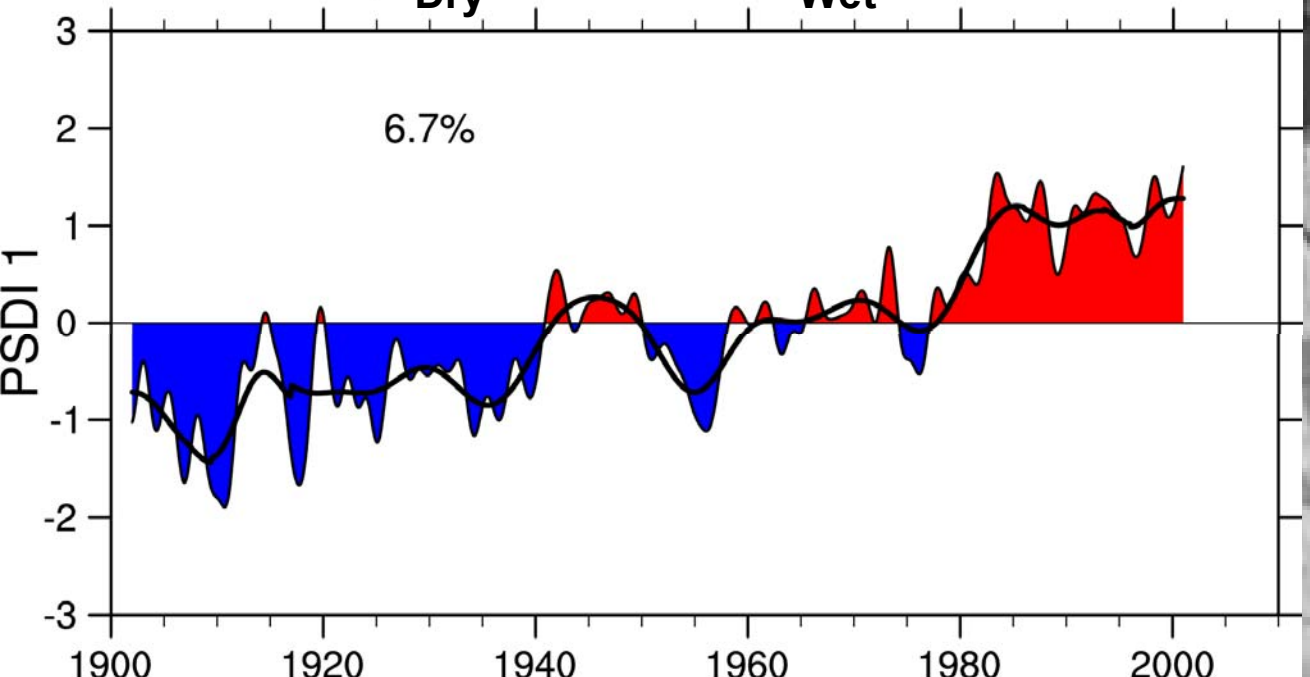
sea ice

and

snow cover:

Snow melts earlier by 1-2 weeks



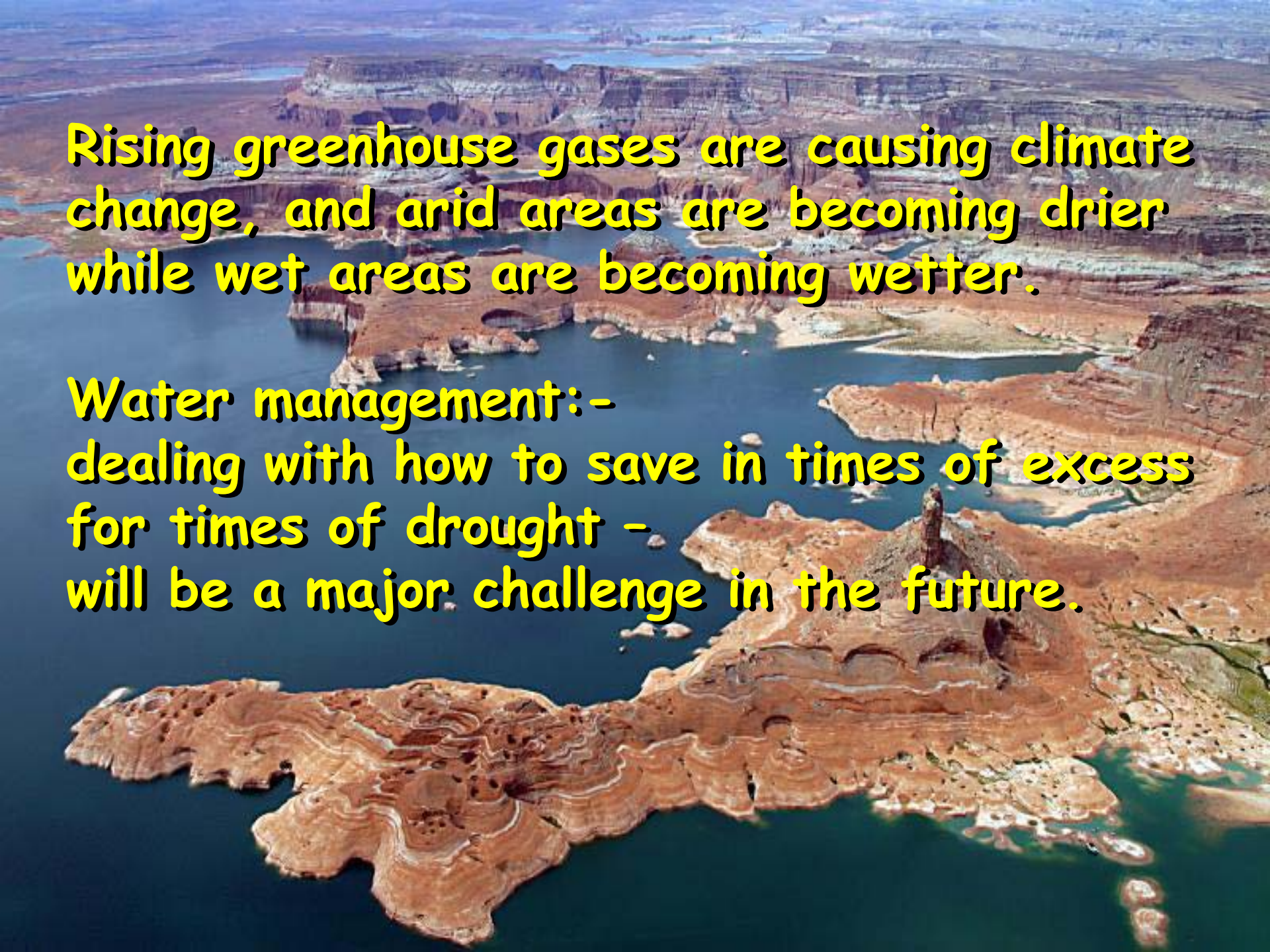


Drought is increasing:

Palmer Drought Severity Index

Dominant pattern has upward trend.

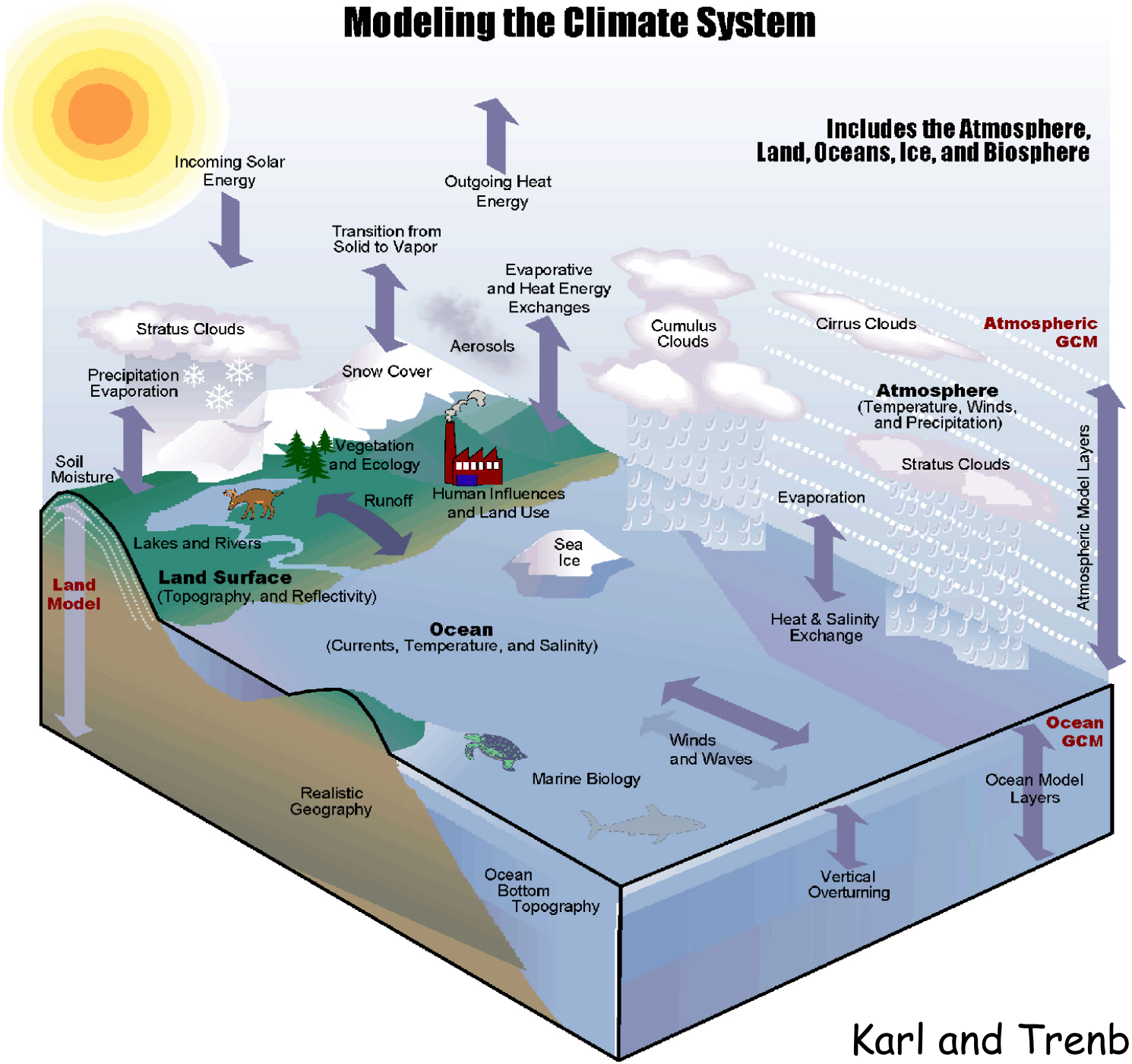
Dai et al 2004



Rising greenhouse gases are causing climate change, and arid areas are becoming drier while wet areas are becoming wetter.

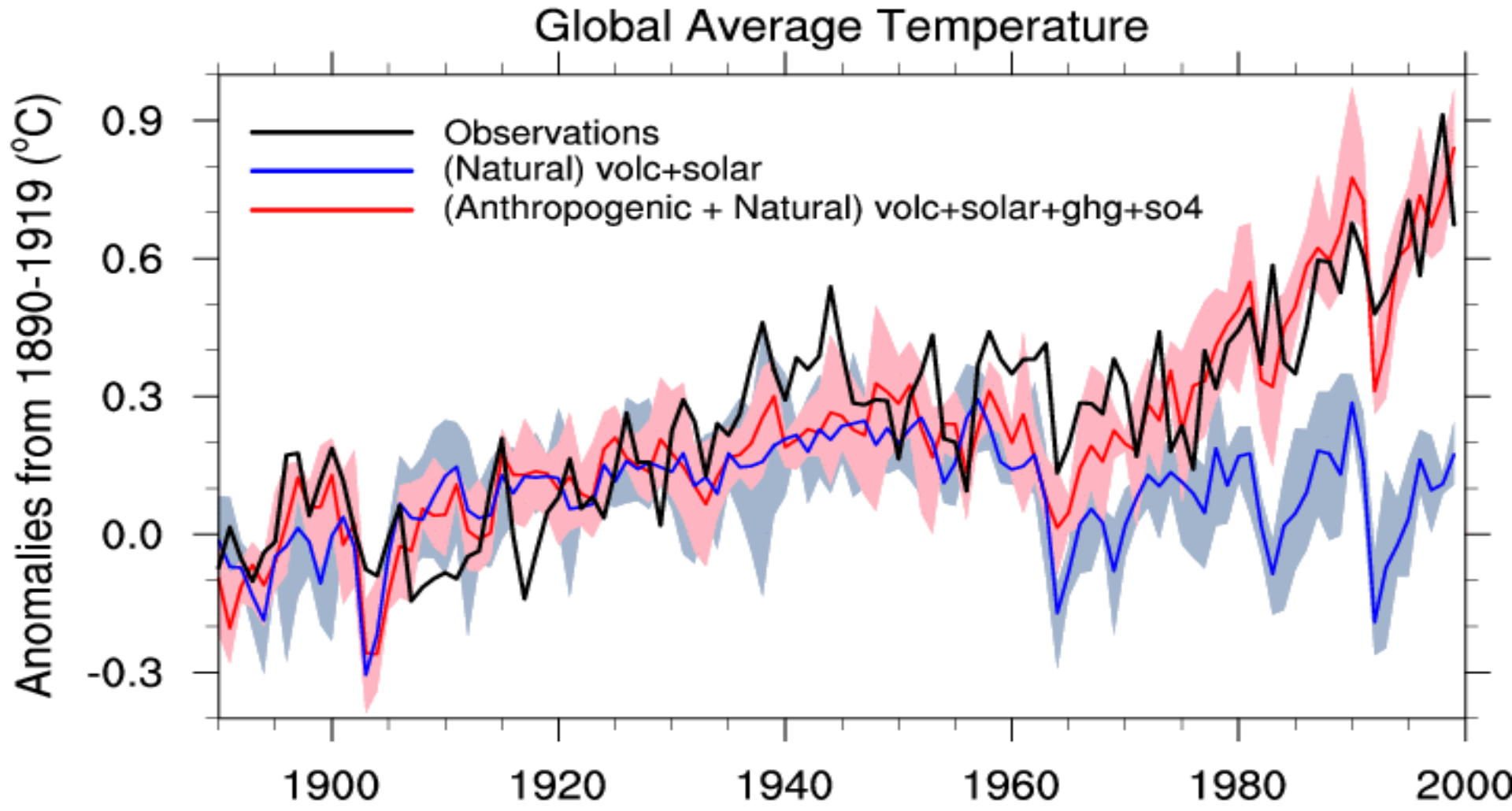
Water management:-
dealing with how to save in times of excess for times of drought –
will be a major challenge in the future.

Modeling the Climate System



Karl and Trenberth 2003

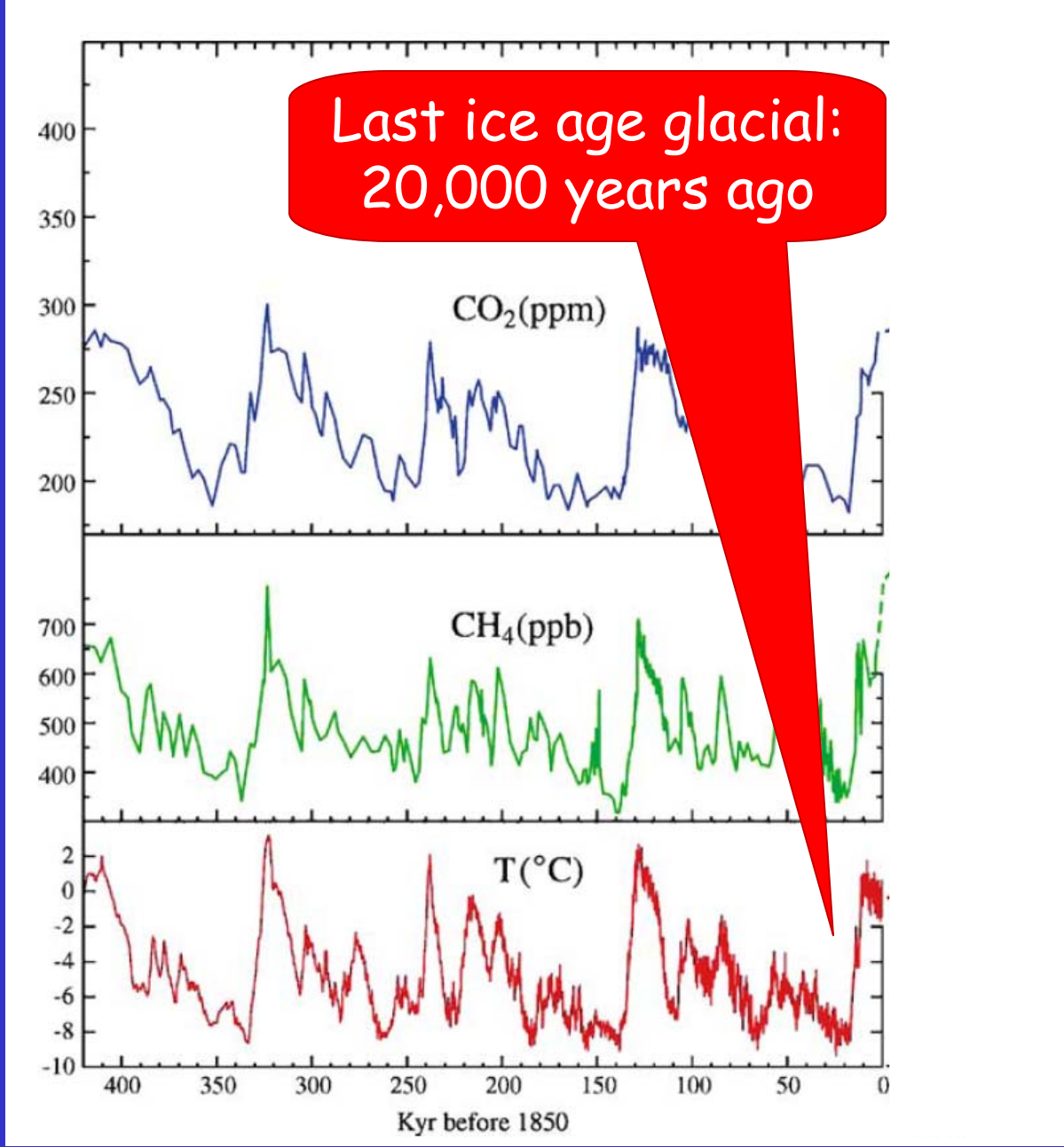
Natural forcings do not account for observed 20th century warming after 1970



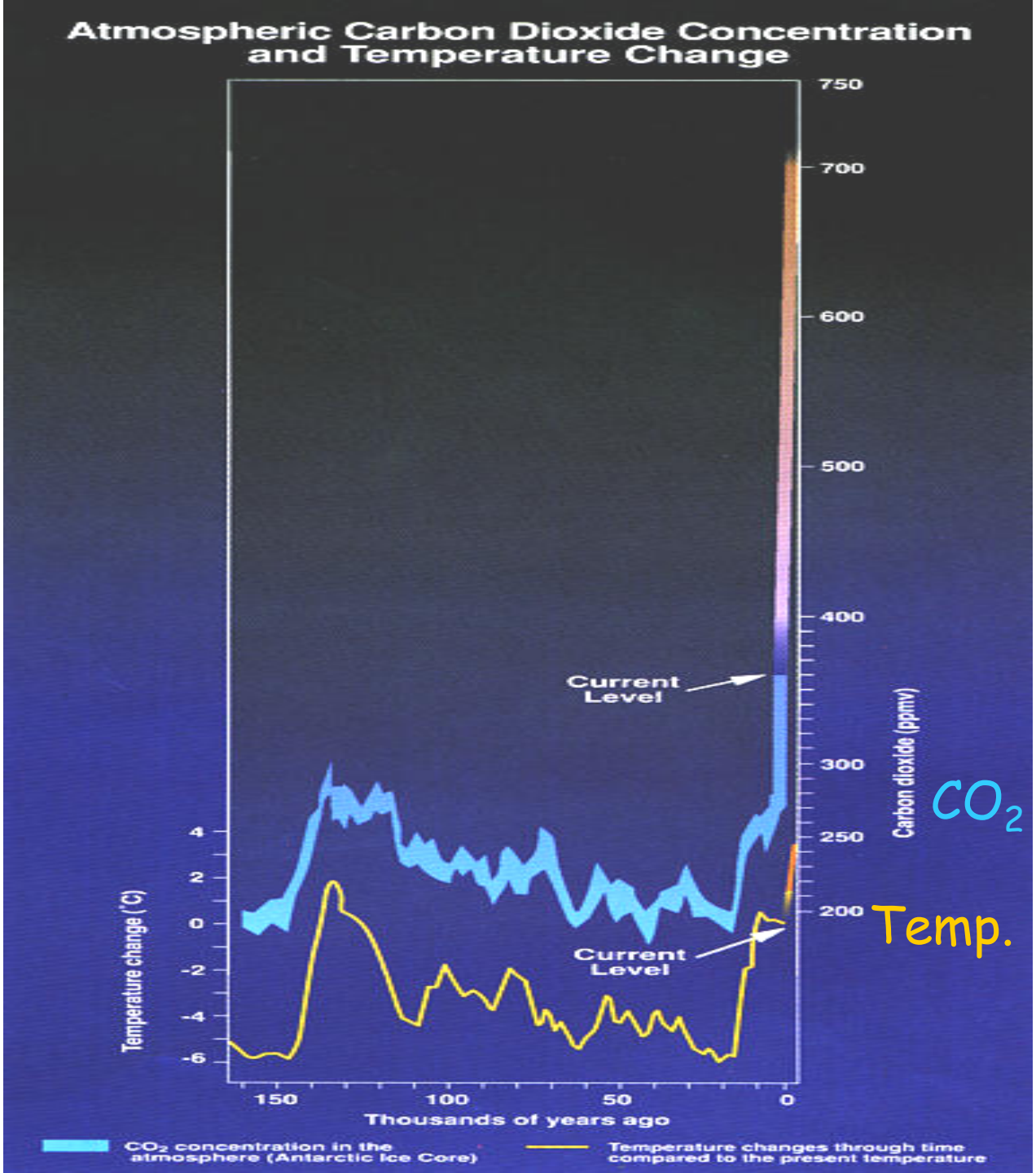
Meehl et al, 2004: J. Climate.

Context:

400,000 years of Antarctic ice core records of Temperatures, Carbon dioxide and Methane.



Source: Hansen, Climatic Change 2005, based on Petit, Nature 1999


Atmospheric Carbon Dioxide Concentration and Temperature Change
750
700
600
500
400
300
250
200
Carbon dioxide (ppmv)
Current Level
Current Level
4
2
0
-2
-4
-6
Temperature change (°C)
150
100
50
0
Thousands of years ago
CO2 concentration in the atmosphere (Antarctic Ice Core)
Temperature changes through time compared to the present temperature
CO2
Temp.